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Canada/NB MDA Project on Mine-shaft Rope Testing; testing of $1\frac{7}{16}$ in., 1×176, F.L.C., H. R., (our rope #6)

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MICROMEDIA

CANADA/NB MDA PROJECT ON MINE-SHAFT ROPE TESTING; TESTING OF $1\frac{7}{16}$ in., 1×176, F.L.C., H. R. (OUR ROPE #6)

by

L.B. Geller*, D. Poffenroth†, J.E. Udd**, and D. Hutchinson††

ABSTRACT

In this report the authors analyse the test-results obtained non-destructively on a $1\frac{7}{16}$ in. diameter, 1×176, full-locked-coil (F.L.C.), hoist-rope (H.R.). The rope was only examined reel-to-reel as part of CANMET's project to comparatively evaluate the performance of a range of EM wire-rope testers. However, results of previous in-situ testing were also available. This is the first time that a project of this magnitude and diversity has been undertaken.

The rope was tested with the Canadian Magnograph, Rotesco AC, and Rotescograph, with the American LMA-250, and with the German WBK instruments. The maximum estimated strength-loss (LBS) was reported as being 1.6% by the Rotescograph operator, and 1.5% by the Magnograph operator. The operators of the American and German instruments did not submit LBS estimates.

Within the context of CANMET's present project it was intended to only test ropes that were in a bad, or very bad, condition. In this context the condition of our rope #6 was too good. However, the results are of interest because they were obtained with a range of five instruments, and five operators. We could, therefore, record comparative results from both a hardware and operator point of view.

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Keywords: New Brunswick; Mineral Development Agreement; Wire-ropes; Non-destructive-testing; Electro-magnetic instruments; Hoist-ropes; Locked-coil ropes

PROJET EEM CANADA/NB SUR L'ESSAI DES CÂBLES DE PUITS DE MINE; ESSAI DE CÂBLE TEC, 1X176, DE 1 7/16 PO (NOTRE CÂBLE NO 6)

par

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RÉSUMÉ

Dans le présent rapport, les auteurs analysent les résultats d'essais non destructifs menés sur un câble de levage (CL) à torons entièrement clos (TEC), 1x176, de 1 7/16 po de diamètre. Le câble n'a été examiné que d'une extrémité à l'autre dans le cadre du projet de CANMET visant à évaluer comparativement les rendements de divers appareils ÉM d'essai des câbles métalliques. Cependant, les résultats d'essais antérieurs menés sur place étaient aussi disponibles. C'est la première fois qu'un projet de cette ampleur et de cette diversité est entrepris.

Le câble a été essayéss avec le Magnograph, le Rotesco AC et le Rotescograph canadiens, avec l'instrument LMA-250 américain et avec les instruments WBK allemands. La perte de résistance (LBS) maximale a été estimée à 1,6 % par l'opérateur du Rotescograph, et à 1,5 % par l'opérateur du Magnograph. Les opérateurs des instruments américain et allemands n'ont soumis aucune estimation de LBS.

Dans le contexte du présent projet de CANMET, le but était seulement de tester des câbles qui sont dans un état mauvais à très mauvais. Dans ce contexte, l'état de notre câble no 6 était trop bon. Cependant, les résultats présentent de l'intérêt parce qu'ils ont été obtenus avec cinq instruments par cinq opérateurs. Nous pourrions donc obtenir des résultats comparables sans égard au matériel ou à l'opérateur.

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Mots clés: Nouveau-Brunswick; Entente sur l'exploitation des minéraux; câbles métalliques; essai non destructif; instruments électromagnétiques; câbles de levage; câbles à toron clos

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BACKGROUND

The results described in this report constitute an integral part of the contracted phase of CANMET's project, undertaken in 1986 in response to requests by both the mining industry and the mine regulatory authorities. The basic project objectives specified that the continuing rope failures, or near failures — occurring despite mandatory wire-rope examinations with electro-magnetic (EM) instruments at regular intervals — be examined, documented, analysed, and the reasons for these occurrences clarified. This is the first time a project of this scope and depth has been undertaken, anywhere.

CANMET's work included both in-house and contracted work phases. The in-house phase resulted in a range of conclusions and recommendations, reported elsewhere (references 1 through 6). We are now in the process of reporting the results obtained during the contracted project-phase, which included an extensive series of both in-situ and shop-floor tests. The first fifteen reports to describe this project phase were prepared in the period February, 1990, through May, 1991 (references 7 through 21). More are to follow.

ROPE DETAILS

The rope of current interest (referred to as "our rope #6") was designated #3 Head Rope in Shaft #2, compartments 1 and 3 (skip and counterweight) of International Nickel Company of Canada's (INCO) Shebandowan mine at Shebandowan, Ontario. It was manufactured by Wire Rope Industries Ltd. of Pointe Claire, Quebec. Its reel number was L-11173. It measured $1\frac{7}{16}$ in. diameter × 2,520 ft. It was of a 1×176 FLC construction (gallery 1: 1×.080; 8×.047; 8×.090; 8×.060; 8×.080; 16×.092; gallery 2: 21×.094; gallery 3: 26×.094; 18×.106; gallery 4: 18×.110/.956; gallery 5: 44×.125 in.), with a mass of 4.85 lb/ft; right regular lay; electro drawn galvanized. Its breaking strength was 262,600 lb (see Ontario MOL test #52126). It was installed on 1979 06 09*, and removed on 1988 09 09, i.e., it was in use for 9 years and 3 months. However, while the rope was in-situ all this time, and tested at regular four monthly intervals, the mine was shut-down from 1985 through 1988.

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*: dates are given in this order: year, month, day

IN-SITU TEST RESULTS — AS REPORTED AND REVIEWED

The Rotesco AC data

In-situ test results were obtained by INCO staff with a Rotesco AC instrument on a routine regulatory basis. Specifically, EM tests were performed on: 1980 01 24; 1980 05 30; 1980 09 26; 1981 01 29; 1981 05 08; 1981 09 17; 1982 01 14; 1982 05 13; 1982 10 27; 1983 03 01; 1983 06 23; 1983 10 20; 1984 03 02; 1984 06 14; 1984 10 25; 1985 08 15; 1985 11 15; 1986 03 12; 1986 09 30; 1987 02 27; 1987 09 24; and 1988 01 26. The LBS_{max} estimates indicated: (a) no loss from January, 1980, to January, 1981, (b) a 1.0% loss from May, 1981, to January, 1982, (c) a 2.0% loss from May, 1982, to October, 1984, and again from September, 1986, to September, 1987, (d) a 2.5% loss from August, 1985, to March, 1986, and (e) a 3.0% loss on 1988 01 26. Up to October, 1984, the LBS_{max} was reported some 500 ft to 850 ft from start of the test at the #1 skip rope-end, while between August, 1985, and September, 1987, the corresponding location was reported to be at 50 ft from the same rope-end. Finally, on 1988 01 26, a rope-segment from 50 ft to 400 ft from the #1 skip rope-end was said to contain an LBS of 3.0%.

The last in-situ test before rope removal was performed on 1988 05 26 (test #SH-375). A copy of the relevant strip-chart is reproduced in Fig. 1a. The operator reported a loss of breaking strength (LBS) of 6.0% at 380 ft, as well as between 1,000 ft and 1,500 ft from start of the test at the #1 skip rope-end. Since, for this rope-size, the operator used a %LMA (loss-of-metallic cross-sectional area) to %LBS conversion factor of 1.5, the reported 6.0% LBS would indicate a 4.0% LMA at the given rope locations. Nowhere along the approximately 2,250 ft of tested rope-length could we, however, detect a %LMA chart-reading of 4.0%. Our maximum %LMA (LMA_{max}) chart-reading was 1.6% at the two rope-ends (Fig. 1a). The 0.0% LMA was within the very 1,000 ft to 1,500 ft rope segment where the operator reported maximum losses. Perhaps, the operator was misled by the conspicuous perturbation of the 'R' (i.e., eddy-current) chart-trace at rope-sections 330 ft, 1,000 ft, 1,190 ft, and 1,220 ft from the start of the test.

SHOP-FLOOR TEST RESULTS — AS REPORTED AND REVIEWED

General procedure

The shop-floor tests were undertaken, reel-to-reel, with a Rotesco AC, a Rotesco-graph, a Magnograph, and an LMA-250 instrument, as well as with the prototype

version of the latest German WBK tester. None of the operators knew about each other's results before these were submitted to us. All details of the testing process were described, and illustrated, elsewhere (7).

Rather than the full 2,250 ft rope-length that was tested in-situ, only some 900 ft (i.e., much less than half the total length) were available for shop-floor testing. Unfortunately, we were not told from which part of the in-situ rope this length was cut. Nor could we detect any characteristic rope-defects along the LMA chart-traces, that might have answered this question unequivocally. Moreover, we could not detect any consistency in the Rotesco AC instrument's eddy-current traces, on comparing those of Figures 1a and 1b. We believe, though, that the shop-floor rope-length might, perhaps, represent the last 900 ft of the strip-chart reproduced in Fig. 1a, i.e., the counterweight (ctwt) rope-end.

The Rotesco AC data

The Rotesco AC data were obtained on 1989 04 03, a day before the permanent magnet instruments were used. This was done to ensure proper rope demagnetization. The shop-floor strip-chart is reproduced in Fig. 1b. We assume that testing started at the counterweight rope-end.

The seizing wire markers, on a 250 ft spacing, did not show up well, and were not identified by the operator on the strip-chart. Instead rope-kinks were marked with a symbol 'K'.

The operator, quite correctly, set the 0.0% LMA reference level at the 850 ft rope-end of the shop-floor test run. On comparing Figures 1a and 1b it may be noted that the reference level at 850 ft from test-start is some 0.4% below the 0.0% LMA reference level of the in-situ rope. The operator reported LMA chart-readings of 1.6% at 110 ft; 1.6% at 390 ft; and 2.0% at 420 ft from test start. The latter two footage values also represent kinked rope locations. In the operator's report the 2.0% LMA_{max} represents an LBS_{max} of $2.0\% \times 1.5 = 3.0\%$.

We think that the LMA chart-readings could, perhaps, be slightly less than reported (see Fig. 1c). However, the differences are of little practical consequence: 1.4% vs 1.6%, and 1.5% vs 1.6%. Our LBS_{max} is, therefore, 2.3% rather than the operator's 3.0%.

The Rotescograph data

The operator tested some 932 ft of rope on 1989 04 04 (Fig. 2a) and some 850 ft on 1989 04 10 (Fig. 2b). The first test started at the counterweight rope-end, and the second at the skip rope-end. The seizing wire 'markers', on a 250 ft spacing, showed up well. The operator identified them by writing 'Marker' on the chart. The location of the rope-kinks was also noted (Fig. 2a). No LMA chart-readings were recorded. We added the 100% reference level and the LMA_{max} value to Fig. 2a ourselves. No report was submitted for the 1989 04 04 test run. For the 1989 04 10 test, though, the operator reported (report #ME0009RPN) an LMA_{max} of 0.8% at 500 ft from the start of the test, with a corresponding LBS_{max} of 1.6%. Rope markers and kinks were noted on the strip-chart. We ourselves entered the 100% reference level onto the operator's chart (Fig. 2b).

We think the operator might have reported an LMA_{max} chart-reading of 1.0%, rather than 0.8% — an insignificant difference of opinion, though.

The Magnograph data

The operator reported (report #89-286E) having tested, on 1989 04 04, a rope length of 897 ft (Fig. 3). The seizing wire markers, on a 250 ft spacing, did not show up well. In Fig. 3 three (out of the four actually present) are identified by the symbols 'Mk 0 pi'; 'Mk 250 pi'; etc. The rope-kink locations are also identified. Testing started at the counterweight rope-end. An LMA_{max} of 1.5% was reported some 164 ft after the 'Mk 0 pi' rope-marker location. The LBS_{max} was reported to be equal to the LMA_{max}, i.e., some 1.5%.

We agree with the reported data.

The LMA-250 data

The operator reported having tested a rope length of some 887 ft (Fig. 4) on 1989 04 04. The seizing wire markers, on a 250 ft spacing, showed up well. In Fig. 4 three (of the four actually present) are identified by the symbols 'M1'; 'M2'; etc. Rope-kink locations were also marked. Testing started at the counterweight rope-end. The 0.0% LMA reference level was placed here. An LMA_{max} of 1.6% was read off the chart near marker M3, at about 700 ft from test-start. No LBS estimates were submitted.

We agree with the reported data. We note, though, that the operator placed the 100% reference level at the counterweight rope-end. On other charts this level seemed to be at the other rope-end. There was, in fact, very little LMA difference between the two rope-ends (see Table 1).

The WBK data

Shop-floor testing was performed on 1989 04 10 with the German WBK instrument — concurrently with the second Rotescograph test-run. The rope length tested was 909 ft (277 m). The strip-chart contains, reading from top-to-bottom: five LF traces, a %LMA trace, and a length indication scale (in meters). There is also space for a second %LMA trace and for a rope-diameter indication-trace (not used in the current test-series). With the sensor-head closed, the individual measuring coils LF #1 and LF#2 were joined together, and so were #3 and #4. The fifth LF chart-trace summarizes the output of these two individual traces. Surface defects, such as the seizing-wire markers, were particularly conspicuous on this instrument's LF and LMA traces.

The two WBK operators carefully annotated their charts, including some LMA readings, kink locations, and the seizing-wire marker (M1 to M4) locations. They also submitted a report. Testing commenced at the skip rope-end. There was no LMA difference between the two rope-ends.

We did not receive a copy of the complete strip-chart. Instead copies of the important chart sections were submitted, numbered Figures 6.1 to 6.11, inclusive. We reproduce these as our Fig. 5. As may be seen, the 0.0% LMA reference level was set along the skip-end rope section; the %LMA scale was 0.298% per mm of full-scale diagram (see 'Fig. 6.1' of our Fig. 5). We added our own marking of the height of the %LMA chart-spikes at the seizing-wire markers. Test results are tabulated in Table 1.

The German report included a tabulation of the M1 to M4 marker locations. It is interesting to note that the tabulated distance between these markers was consistently 76 m (249.3 ft). The corresponding 'true' distance was 250 ft.

We agree with the operators' report.

DESTRUCTIVE TESTING

The in-situ and reel-to-reel shop-floor tests of rope #6 did not indicate any deterioration of sufficient severity to warrant destructive testing of any of the rope segments.

ANALYSIS OF TEST RESULTS

(1) General comments

Considering the influence of the instrument calibration-procedures upon the test-results, we included relevant information about these matters in Table 1, such as: (a) the rope-end at which calibration was effected, (b) the rope-segment at which 0.0%LMA was found to be, and (c) the %LMA difference between the two rope-ends.

Since the sequence of events commenced at the skip rope-end in some cases, and at the counterweight rope-end in others, for easier orientation we included in Table 1 the distance of the rope-kinks and rope-markers from a consistent reference point, namely from the skip rope-end.

Wherever we were unable to reproduce the strip-charts in a single length, we provided match-marks (such as: ref. 'A'; ref. 'B'; etc.) on the individual chart-segments. Moreover, we added to all charts: (a) the 100% reference levels, (b) the relevant sensitivity scales (%LMA per major chart-division), and (c) the %LMA chart-readings at the most important rope-locations. It should be noted that our rope #6 represented much less than half of the original, in-situ, rope-length. Moreover, its 0.0% LMA level was, in all likelihood, some 0.4% below the 0.0% LMA reference level of the in-situ rope.

The rope was in a relatively good condition. The major interest in examining it was the opportunity to compare test-results obtained with five different instruments, and operators.

Details of the test set-ups are listed in Table 2.

(2) LF chart-readings

Broken wires were not of major significance. Nor was there evidence of any corrosion of consequence. However, there were significant rope-kinks. The LF chart-traces were particularly useful in locating these kinks and the rope-markers.

(3) LMA chart readings

We tabulated the %LMA chart-readings in Table 1. We agree with the reported values for the shop-floor test series. However, we think that the operator misread the in-situ strip-chart.

Comparative evaluation of the five EM instruments used can, perhaps, be best based on the LMA_{max} chart-readings (Table 1). The %LMA chart-readings at characteristic rope-anomalies, such as the three major rope-kinks and four rope-markers (M1 through M4), were too small for accuracy, and to be meaningful. These markers consisted of $\frac{1}{16}$ in. diameter wire, wound around the $1\frac{7}{16}$ in. rope at 250 ft intervals along 2 in. stretches. Noting that the metallic cross-sectional area (A) of the rope itself was assumed to be 1.2887 in^2, addition of the seizing-wire represented a metallic area increase — i.e., LMA 'spike' — of some 20%. Only the 'spikes' on the WBK chart-traces were sufficiently large to permit reasonably accurate scaling. The 'height' of these spikes was: 1.6%; 1.8%; 2.8%; and 0.9% for the markers M1 through M4, respectively, with M1 being closest to the skip rope-end.

In this context, though, we must also mention the physical instrument characteristic usually referred to as 'quantitative resolution'. As an example, for the Magnograph we noted (see Fig. 32c in ref. 7) that a 2.0 in. long rope-anomaly will only produce some 36% of the numerically correct reading on the instrument's LMA strip-chart. In the present case, therefore, only some 36% of 20%, or about 7.2%.

Apart from the kinks, this rope was in a relatively good condition, with the LMA_{max} not exceeding 1.6%. Under these conditions the Magnograph operator's LMA setting of 2.5% per chart-division is inappropriately insensitive.

(4) LBS estimates

Since we did not perform any destructive rope testing, we had no way of checking the accuracy of the operators' LBS estimates. These were, in any case, too small to be of any practical interest.

(5) Repeatability and comparability

It is remarkable how consistently the different instruments, and operators, produced the same qualitative results. There were few, if any, characteristic rope anomalies. Quantitative comparisons were of little interest, due to: (a) the uncertainty about the true location of the 100% reference level, since the total original rope-length was not available, and (b) the relatively good condition of the rope.

We could not make any meaningful comparisons between the in-situ and shop-floor test results, because the full in-situ rope-length was not available to us on the shop-floor. In such a case only total-metallic-area (TMA) measurements, as described elsewhere (17), can provide legitimate comparisons.

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APPENDIX

Tables 1 and 2

as well as Figures 1 through 5, inclusive

Table 1

In-situ and shop-floor test-results

Subject	In-situ	Shop-floor					
	Rot. AC 1988 05 26 Fig. 1a	Rot. AC 1989 04 03 Fig. 1b	Magnogr. 1989 04 04 Fig. 3	LMA-250 1989 04 04 Fig. 4	Rotescogr. 1989 04 04 Fig. 2a	Rotescogr. 1989 04 10 Fig. 2b	WBK 1989 04 10 Fig. 5
tested rope length	2,250 ft	850 ft	897 ft	887 ft	932 ft	850 ft	909 ft
kinks: @ ft*	—	190; 420; 455	231; 426; 450	187; 427; 452	146; 447; 472	165; 379; 399	190; 433; 459; 741
markers: @ ft*	—	190; 430; 640; 802	192; 441; 647; 891	147; 392; 637	154; 412; 670; 926	132; 349; 586; 835	151; 400; 649; 898
Max. %LMA: @ ft*	4.0%‡ 1,000 – 1,500 ft‡	1.5% 460 ft	1.5% 483 – 672 ft	1.6% 700 ft	1.0% 487 – 615 ft	0.8% 500 – 710 ft	1.5% 794 ft
0.0% LMA @:	mid-point††	skip-end	both ends	ctwt-end	skip-end	both ends	both ends
calib. @: skip;	yes	—	—	—	—	yes	yes
calib. @: ctwt;	—	yes	yes	yes	yes	—	—
%LMA diff. betw. ends:	0.2%	0.8%	0.0%	0.4%	0.6%	0.0%	0.0%

‡: as reported, vs authors' chart-reading of 1.6% LMA_{max} at both rope-ends

††: as reviewed by authors; erroneous operator-choice was not reported

*: from the skip rope-end, as per chart

Table 2

Details of EM testing of the $1\frac{7}{16}$ in., 1×176, FLC, H.R.

Item No.	Test Instr.	Test No.	Test date	Test location	Instr. operator*	Test chart: Fig. #
1	Rotesco AC	#SH-375	1988 05 26	in-situ	(4)	1a
2	Rotesco AC	1	1989 04 03	shop-floor	(4)	1b
3	Magnograph	#89-286E	1989 04 04	shop-floor	(2)	3
4	LMA-250	—	1989 04 04	shop-floor	(5)	4
5	Rotescograph	—	1989 04 04	shop-floor	(6)	2a
6	Rotescograph	ME-0009RPN	1989 04 10	shop-floor	(6)	2b
7	WBK	—	1989 04 10	shop-floor	(7)	5

*: (7): instr. designer/maker and service company

(2) service company

(4) and (6): mining company

(5) government organization

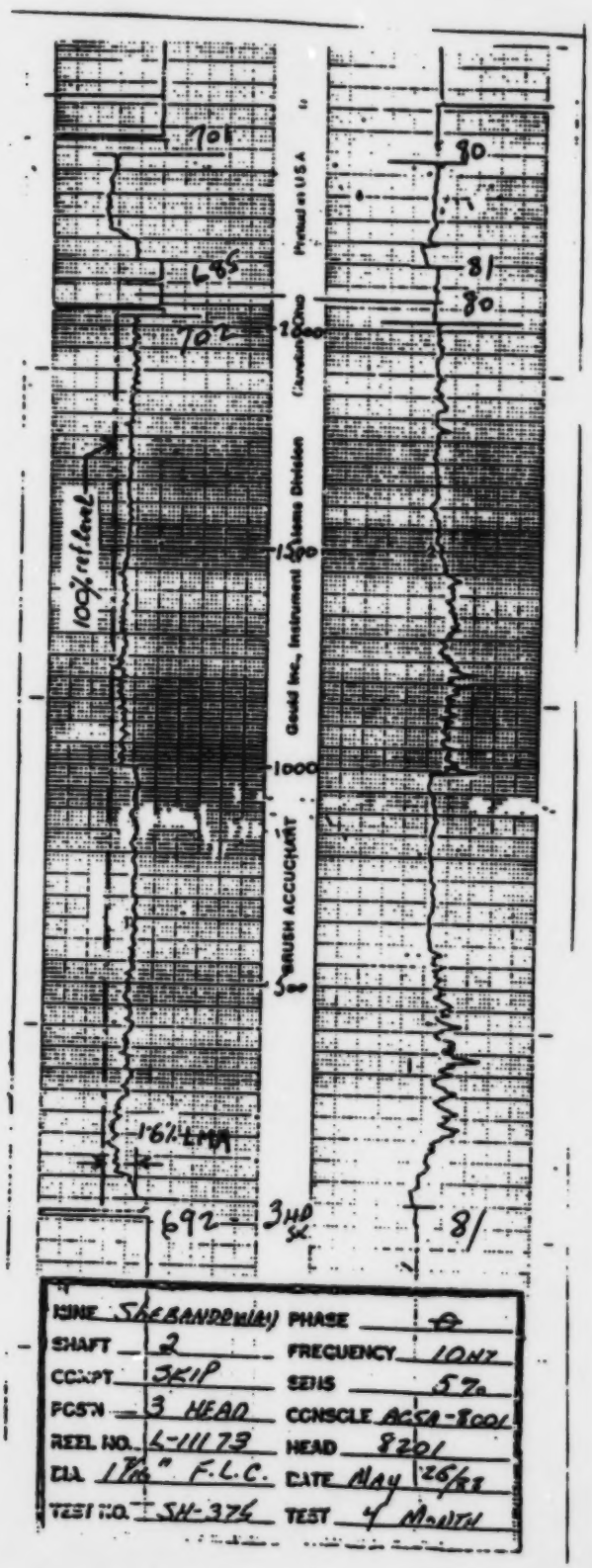


Fig. 1 — Rotesco AC test: (a) in-situ, of 1988 05 26

(b) shop-floor, as reported

Fig. 1 (continued) —

Rotesco AC test, of 1989 04 03

(c) shop-floor, as reviewed

Fig. 2a — Rotescograph test, shop-floor, of 1989 04 04

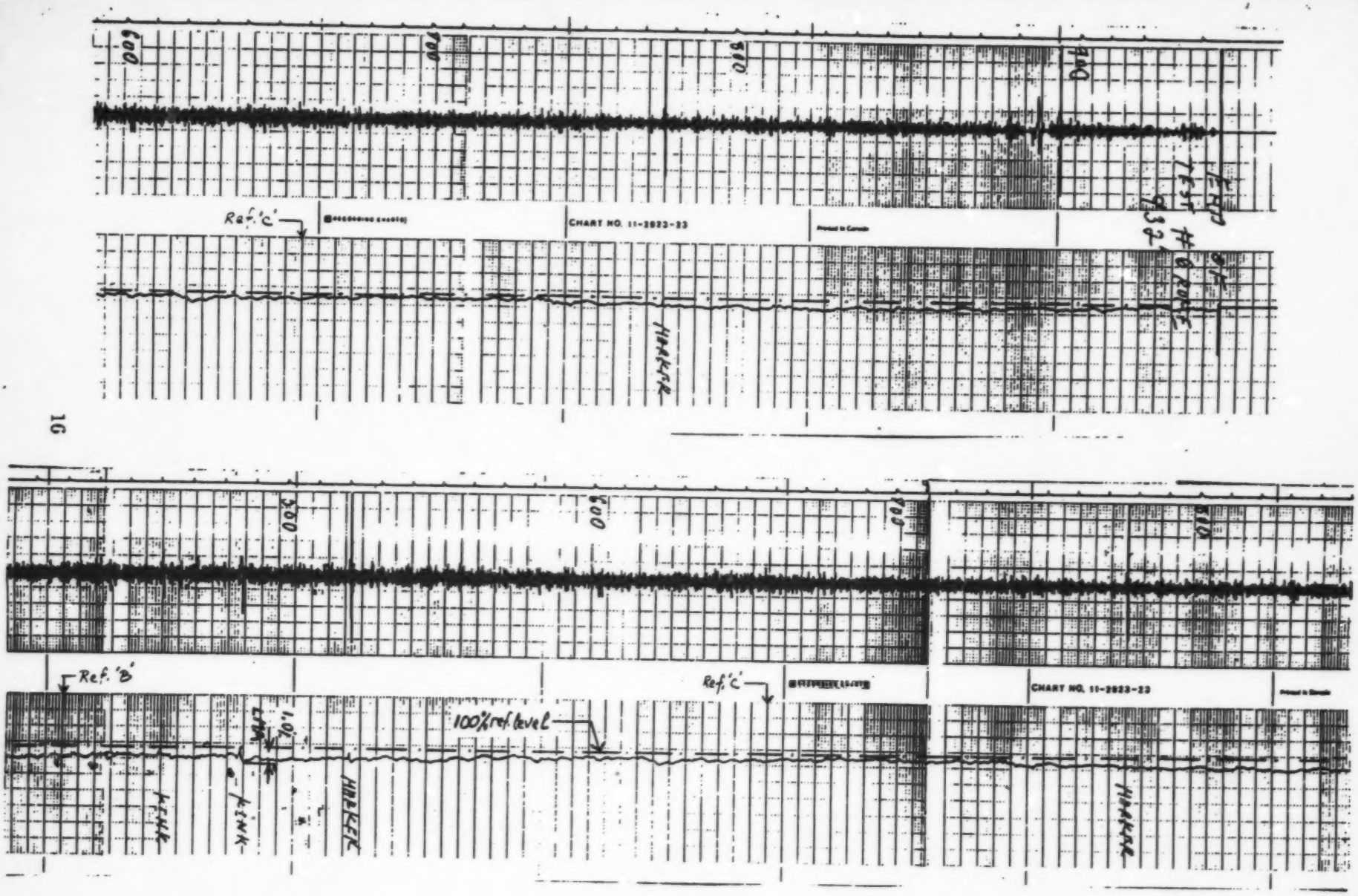


Fig. 2a (continued) — Rotescograph test, shop-floor, of 1989 04 04

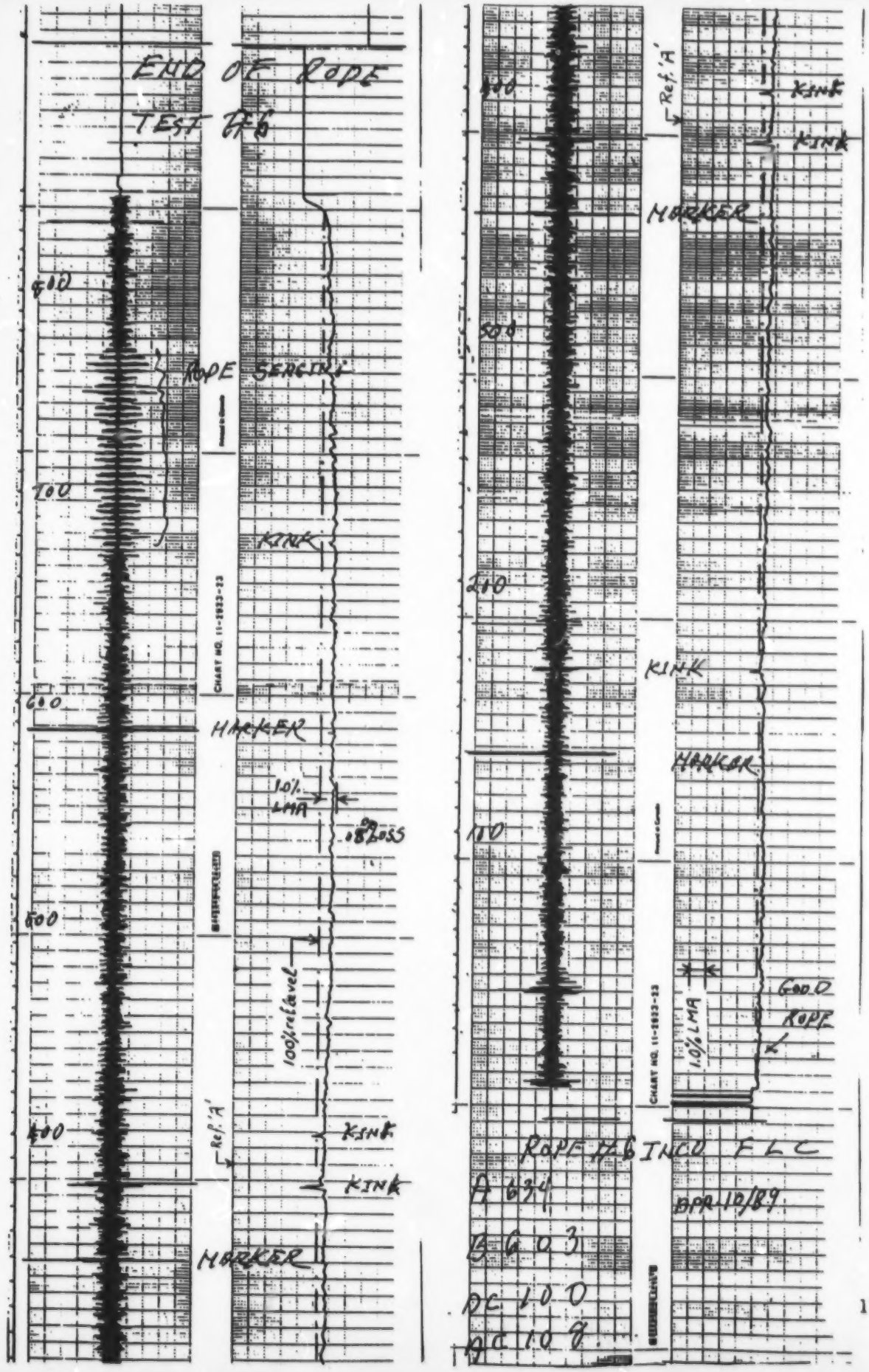


Fig. 2b — Rotascograph test, shop-floor, of 1989 04 10

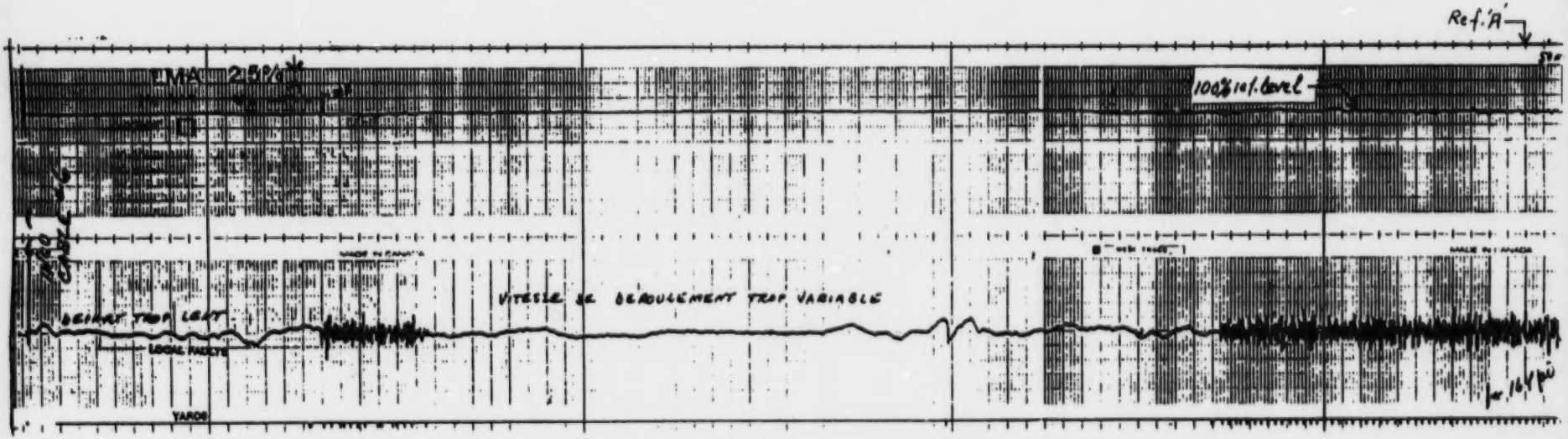


Fig. 3 — Magnograph test, shop-floor, of 1989 04 04

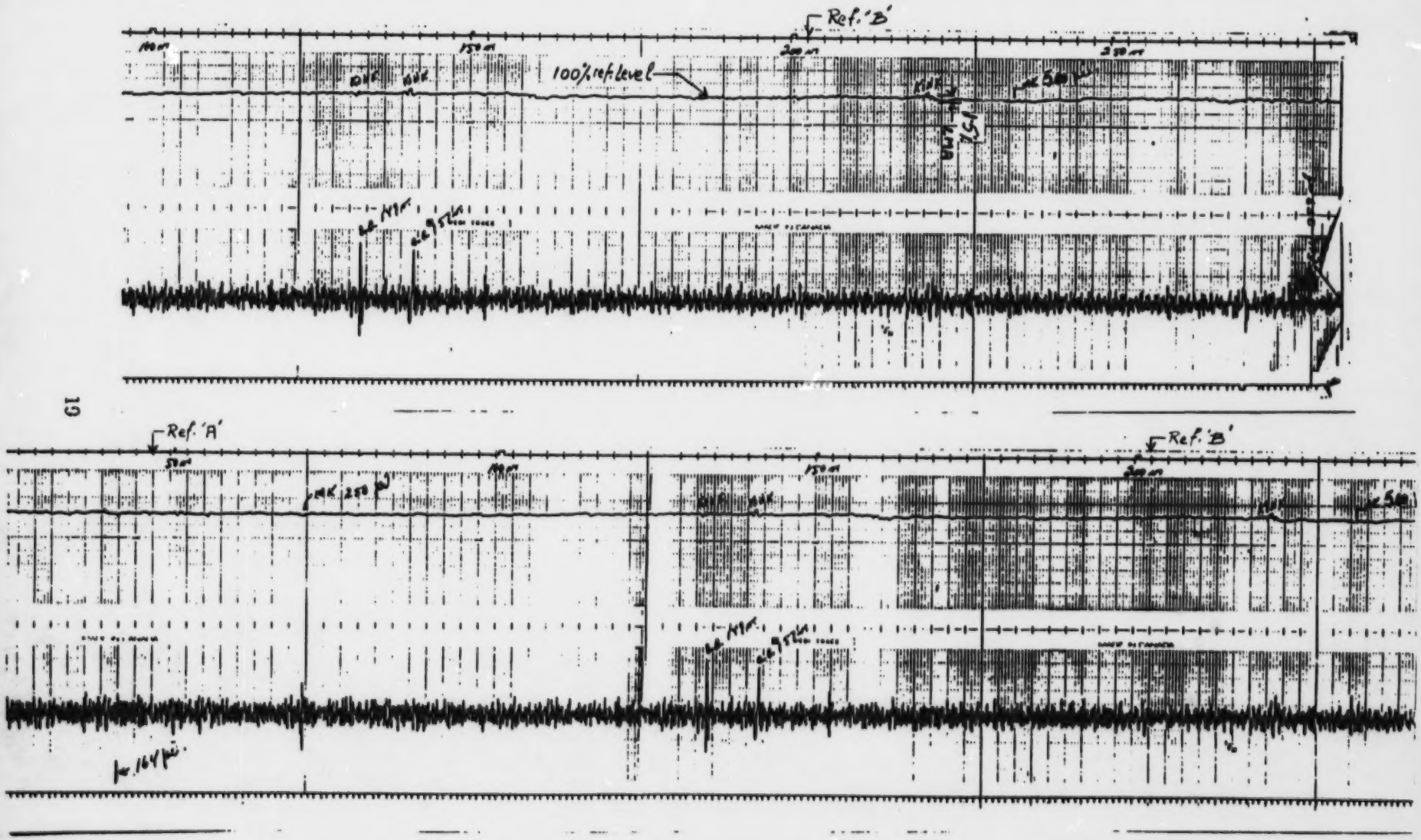
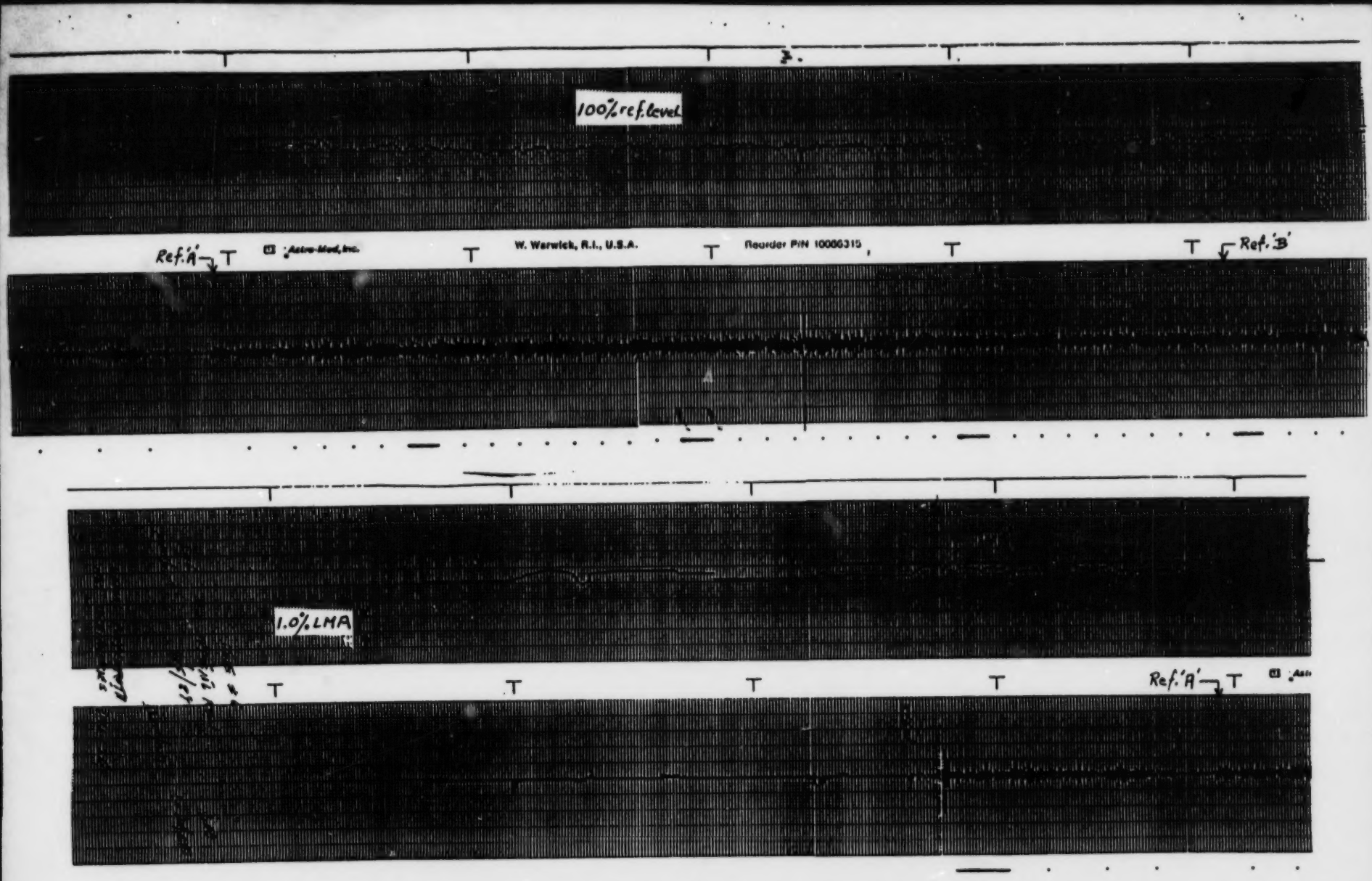


Fig. 3 (continued) — Magnograph test, shop-floor, of 1989 04 04



20

Fig. 4 — LMA-250 test, shop-floor, of 1989 04 04

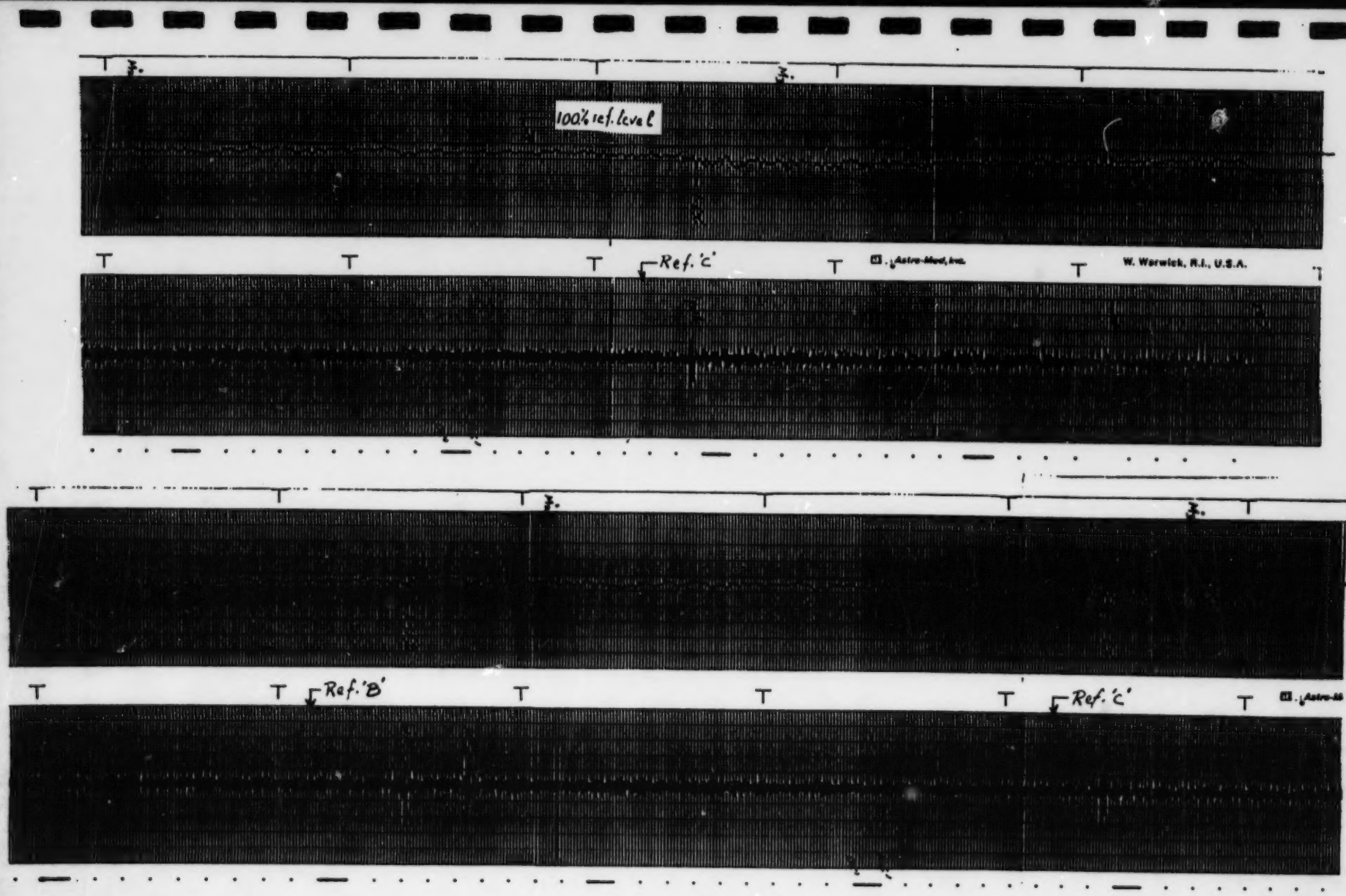


Fig. 4 (continued) LM A-250 test, shop-floor, of 1989 04 04

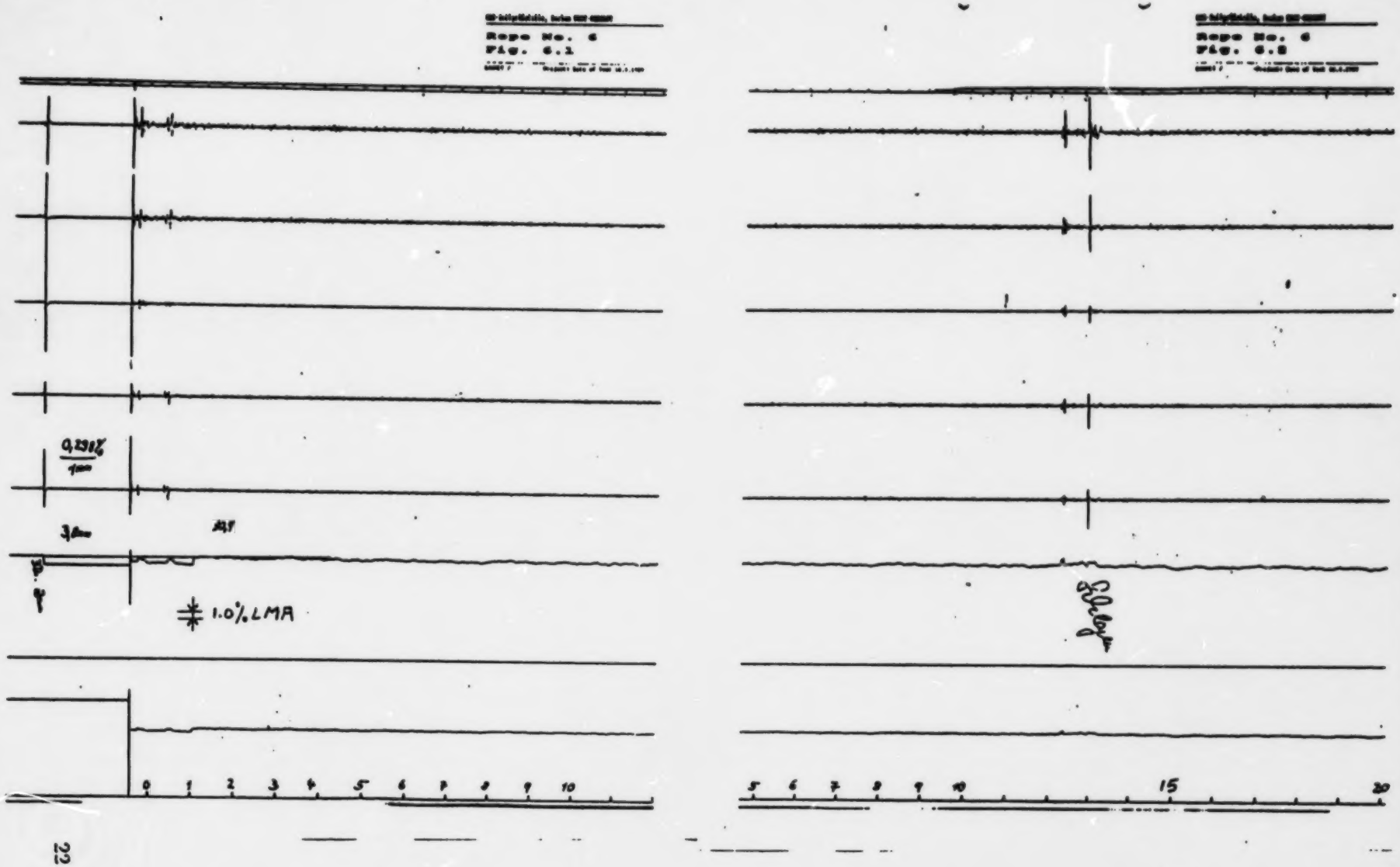


Fig. 5 — WBK test, shop-floor, of 1989 04 10

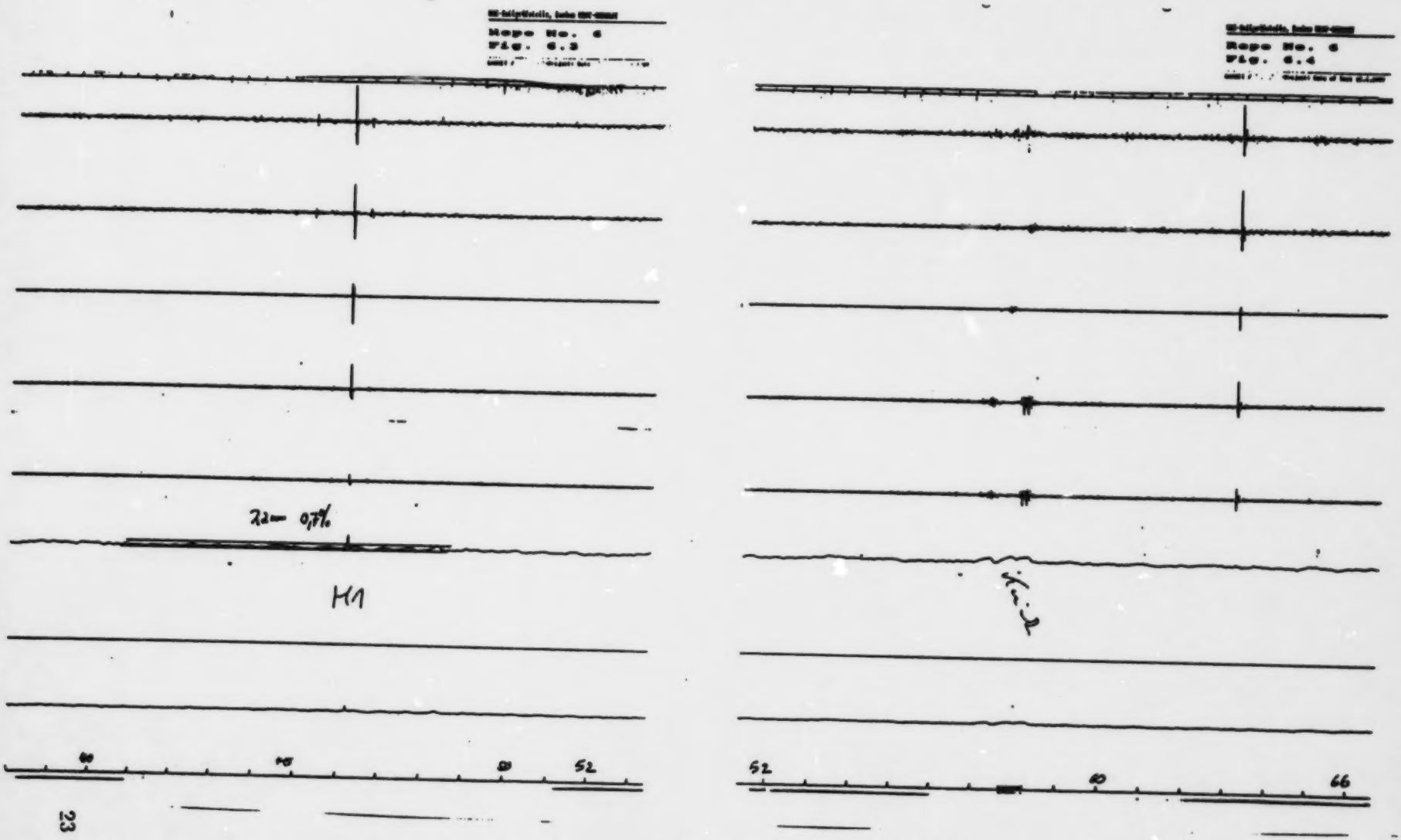


Fig. 5 (continued) — WBK test, shop-floor, of 1989 04 10

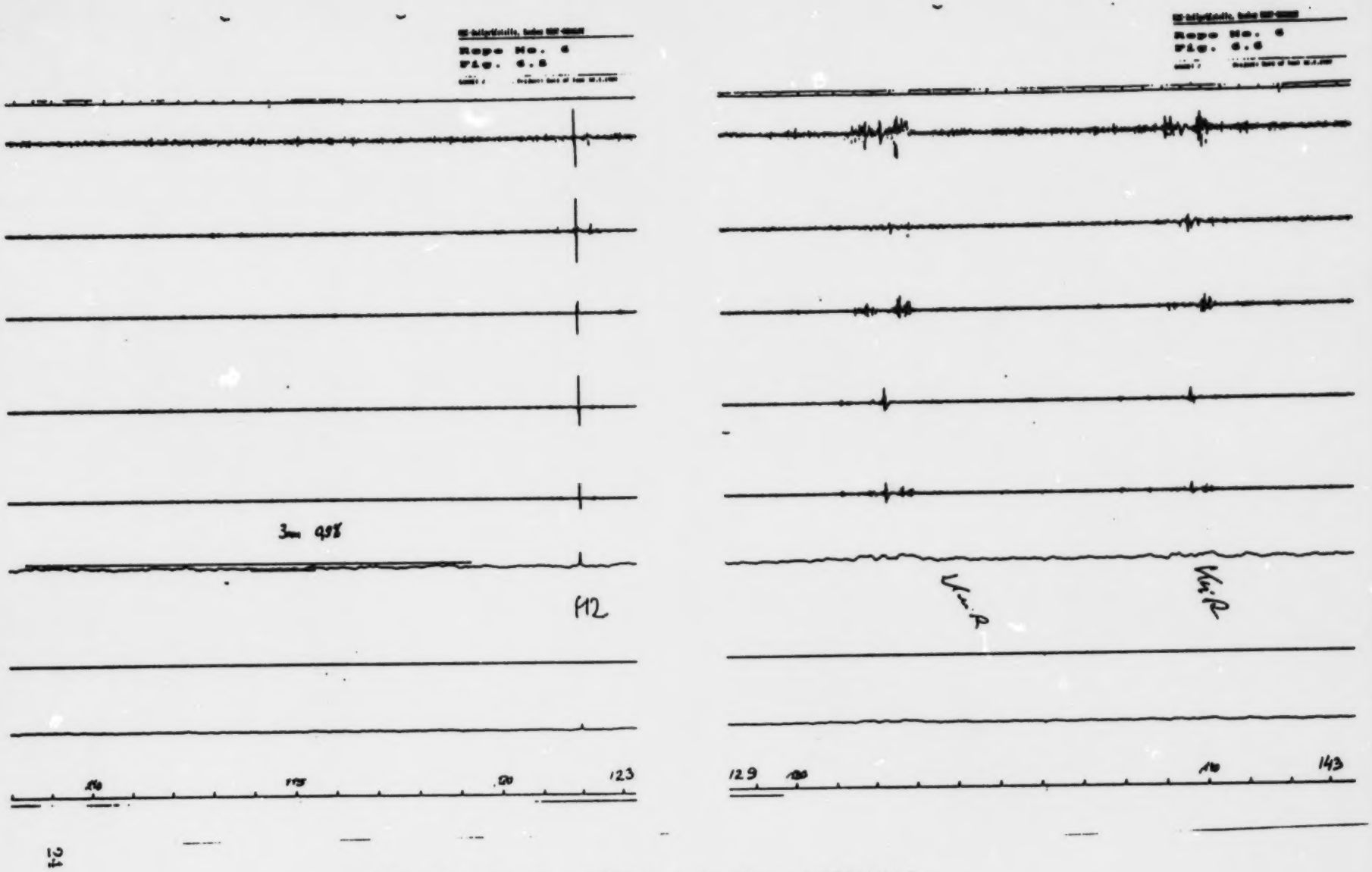


Fig. 5 (continued) — WBK test, shop-floor, of 1989 04 10

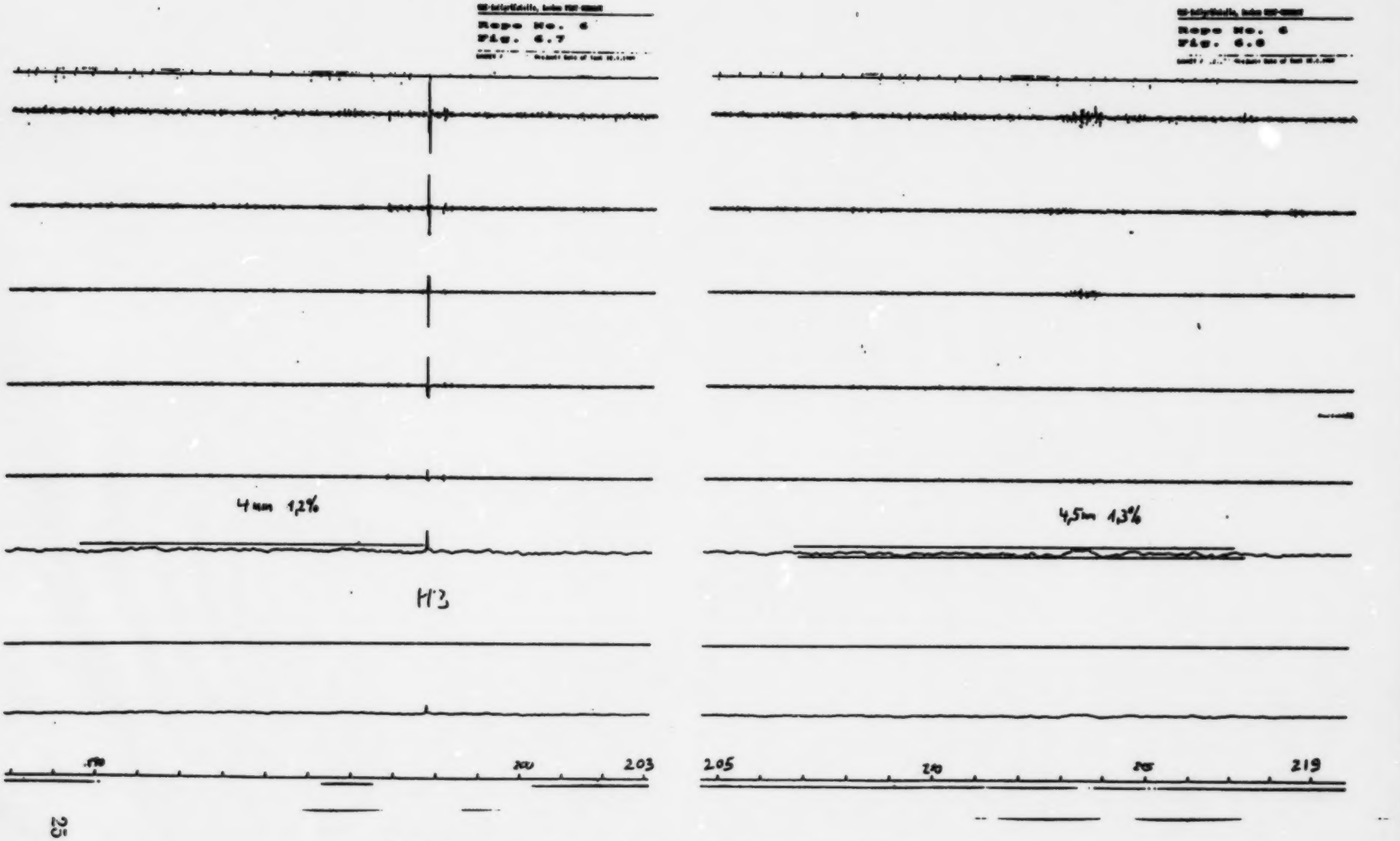


Fig. 5 (continued) — WBK test, shop-floor, of 1989 04 10

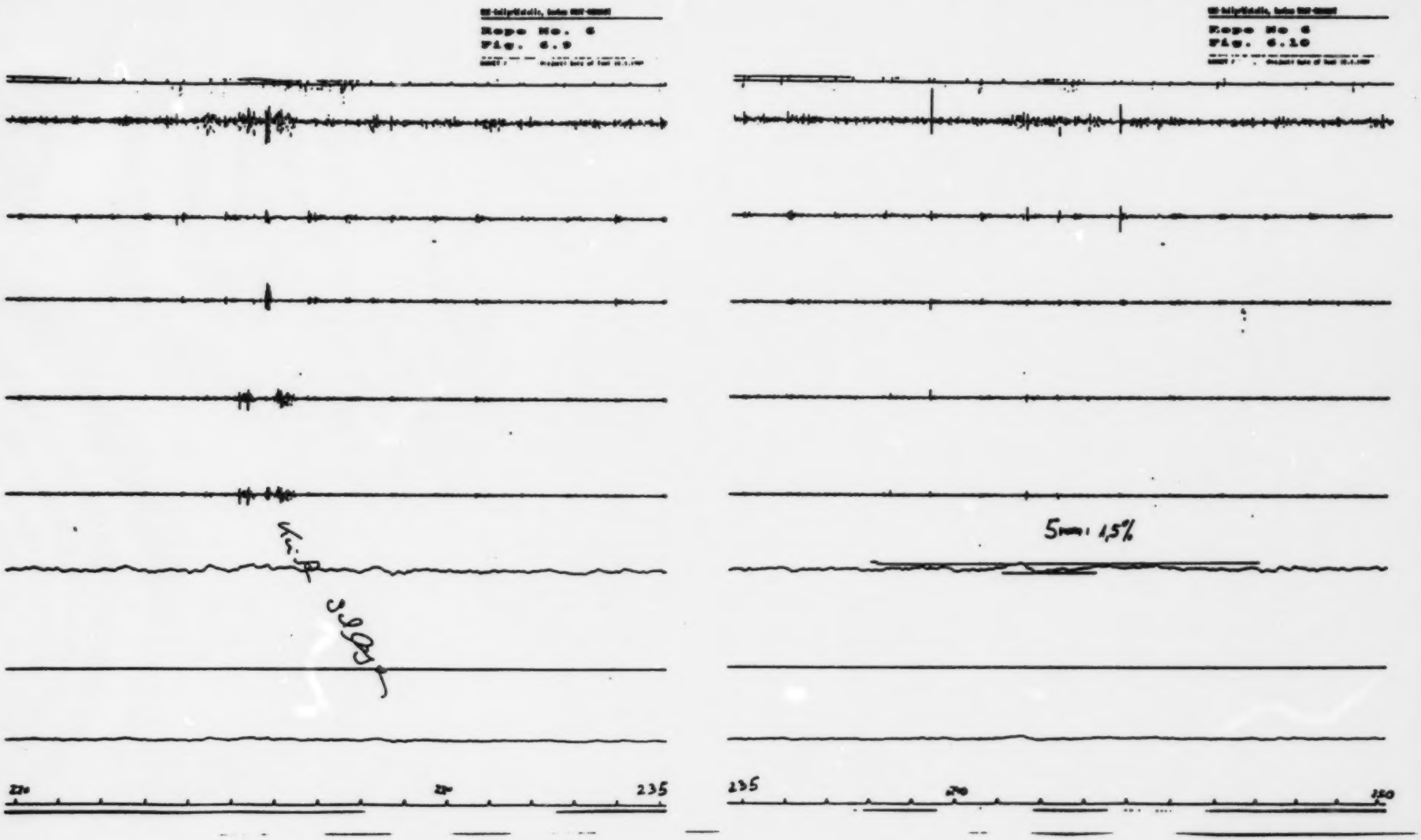


Fig. 5 (continued) — WBK test, shop-floor, of 1989 04 10

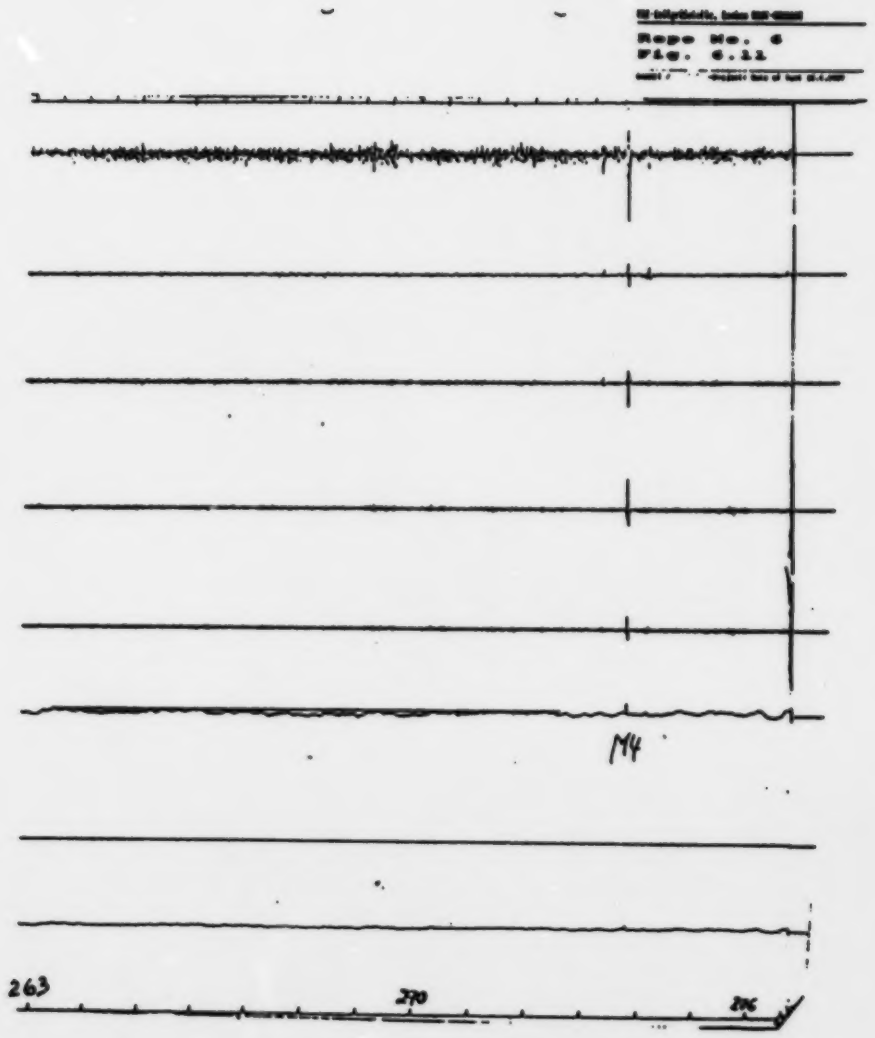


Fig. 5 (continued) — WBK test, shop-floor, of 1989 04 10